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Unit-I

Contents of Unit-I (Foundation): Necessity and types of R.C.C. foundations, Detail of Deep foundation and precast foundation in general, Details shallow foundations. Bearing capacity of soils and its assessment. Presumptive bearing capacity values from codes. Loads on foundations. Causes of failures of foundations and remedial measures, Foundation on black cotton soils Setting out foundation trenches, excavation timbering of foundation trenches. Load bearing and framed structures.

What is Foundation?

Every Building consist of two basic components: The super-structure and the sub structure. The superstructure is usually that part of the building which is above the ground and which serves the purpose of its intended use. The sub structure or foundation is the lowest part of the structure usually located below the ground level, which transmits the load of super structure to the sub soil. A foundation is therefor that part of the structure which is in direct contact with the soil to which the loads are to be transmitted. Foundation provides a base for the superstructure.

Note: The soil which is located immediately below the base of foundation is called sub soil.

Functions of Foundation or Necessities of foundation

The foundation are provided to serve the following purposes.

1) To distribute the load of the superstructure on a larger area, so that the intensity of load at its base does not exceeds the safe bearing capacity of sub soil.
2) Foundation distribute the non-uniform load of a superstructure evenly to the sub soil. For example two columns carrying unequal loads can have a combined footing which may transmit the load evenly to the sub soil. Due to this unequal settlements are minimized.
3) Foundation provides levelled and hard surface over which superstructure can be built.
4) Foundation anchors the superstructure to the ground, thus it provide lateral stability to the superstructure against various forces such as wind, earthquake etc.
5) It provides structural safety against undermining or scouring due to burrowing animals and flood water.
6) Special foundation measure prevents or minimizes the cracks in super structure, due to expansion or contraction of the sub soil because of moisture movements in some problematic soils (Black cotton soil).

Essential Requirement of a Good Foundation

Following are the basic requirements of foundation.

1) The foundation should be safe and stable against all the possible forces which a structure is likely to be subjected to.
2) The foundation should be able to sustain the dead load and imposed loads and transmit these loads to the sub soil in such a way that pressure on it will not cause settlements which would affects the stability of the building.
3) Foundation base should be rigid so that the differential settlements are minimized, especially for case when super imposed loads not evenly distributed.
4) Foundation should be taken sufficiently deep to guard the building against damage cause by swelling and shrinkage of sub soil.
5) Foundation should be so located that its performance may not be affected due to any unexpected future influences.

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Types of Foundation: Foundation may broadly classified under two categories:

a) Shallow foundation
b) Deep foundation

a) Shallow foundation: According to Terzhagi, a foundation is shallow if its depth is equal to or less than its width. ($D \leq B$)
Shallow foundation may further divided into following categories
Types of shallow foundation:
1) Spread footing
2) Combined footing
3) Strap footing
4) Mat or Raft footing

1) Spread footing:

- It spreads the super-imposed load of a wall or a column over a larger area.
- Used where loads are not very heavy and soil has decent amount of bearing capacity.

Following are the different types of spread footing.

1) **Single column footing**: It is used where loads are not heavy and soil has good bearing capacity.

2) **Stepped column footing**: When loads are heavy it requires greater spread thus stepped footing is used when loads are to be distributed over larger area.

3) **Slopped column footing**: In sloped footing concrete base does not have a uniform thickness. It distributed the load uniformly to the sub soil.

4) **Simple Wall footing:** Used for load bearing structure. It is constructed without any step

5) Stepped wall footing: It is provided where loads are relatively higher hence steps are used to distribute load over wider area

6) Grillage foundation: It is a special type of isolated footing generally provided in case heavy steel columns.

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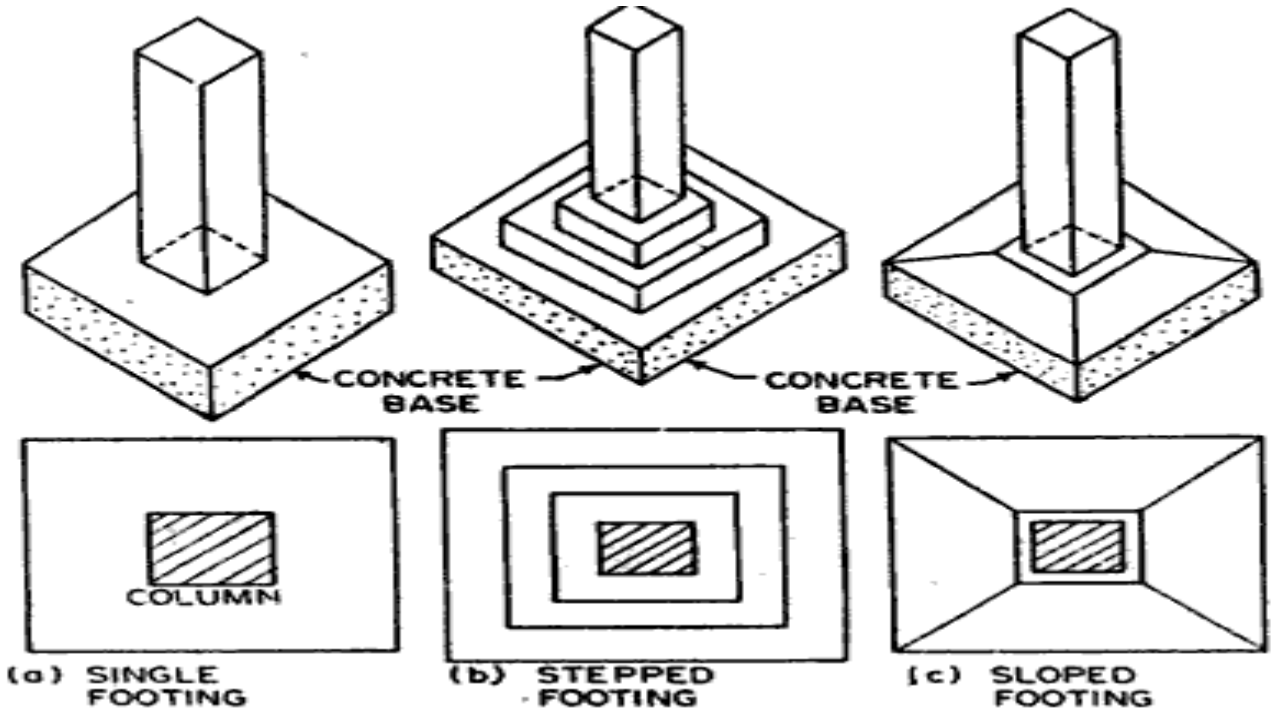
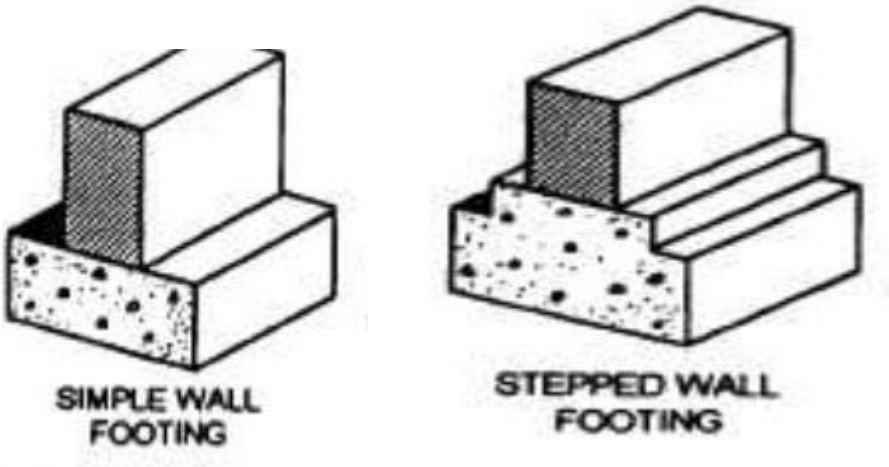
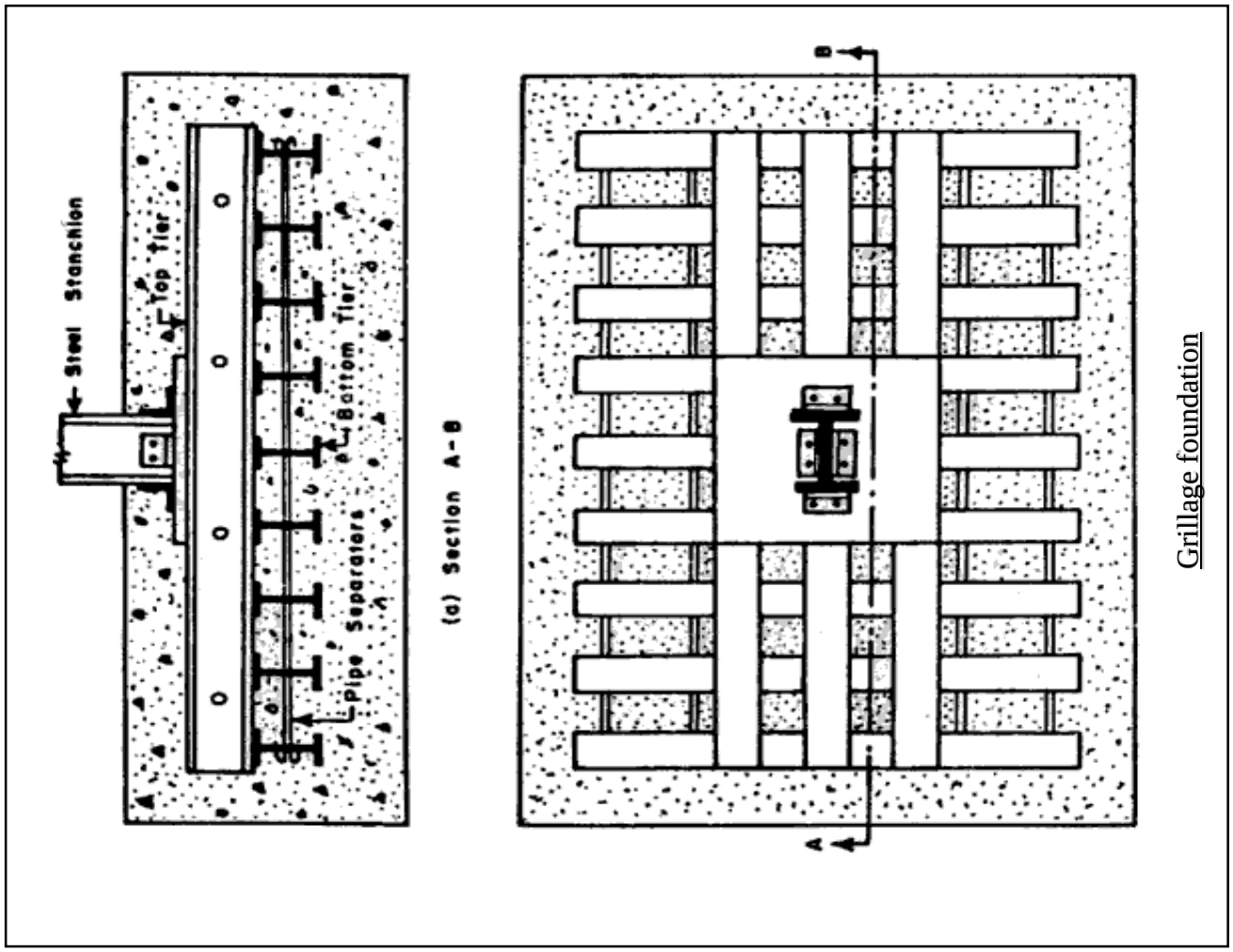




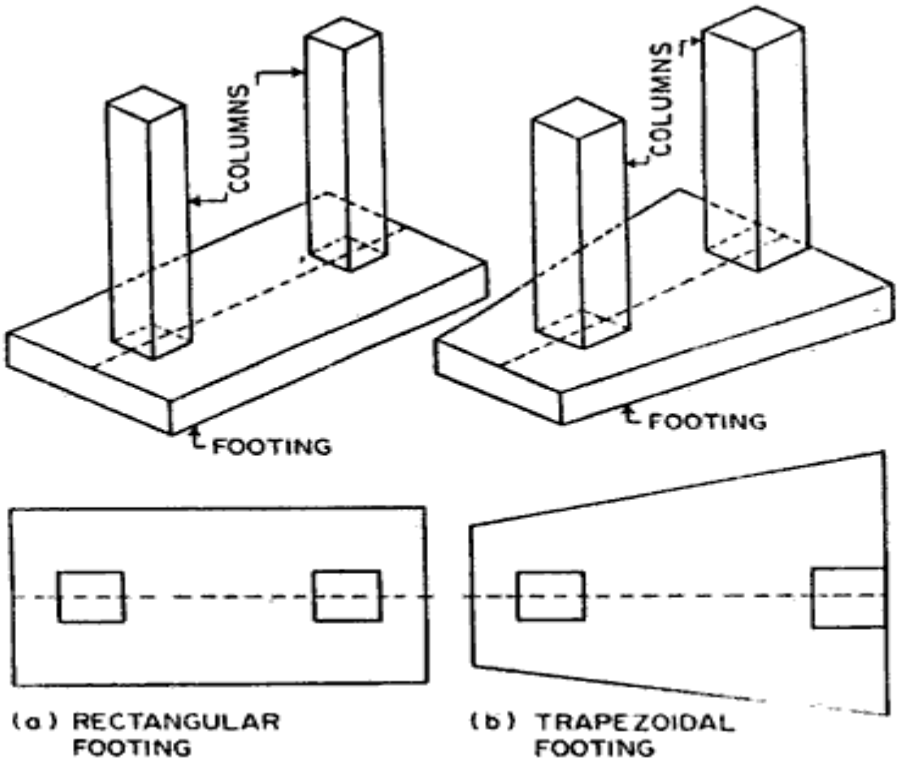
Grillage Foundation:

- It is a special type of isolated footing generally provided for heavily loaded steel stanchions (columns).
- High rise buildings are built with steel columns encased with concrete. Such columns carry very heavy loads hence they need special foundation to spread the load over larger area of soil.
- It is used in those locations where loads are heavy and soil has a poor bearing capacity.
- The depth of such foundation limited to 1 to 1.5m
- Grillage foundation consist of Tiers of I section steel beams. The loads from heavy steel columns is distributed to larger area by means of two or more tiers.
- Each layer of tier is laid at right angle to the layer below it.
- The tiers of joist are then embedded in concrete to keep the I section beams (Rolled steel joist) in position and prevent it from corrosion.
- Pipe separators are used to maintain the spacing between I section beams.
- Grillage foundation is also constructed with timber beams and planks.



2) **Combined Footing:** A spread footing which supports two or more column is termed as combined footing. The combined footing may be of the following types:
   1) Rectangular combined footing
   2) Trapezoidal combined footing

   The combined footing for columns will be rectangular in shape if the columns carry equal loads. The design of rigid rectangular combined footing should be done in such way that center of gravity of column loads should coincide with the centroid of the footing.
   If the columns carry unequal loads then trapezoidal shape footing is provided to distribute the unequal column loads evenly to the sub soil.



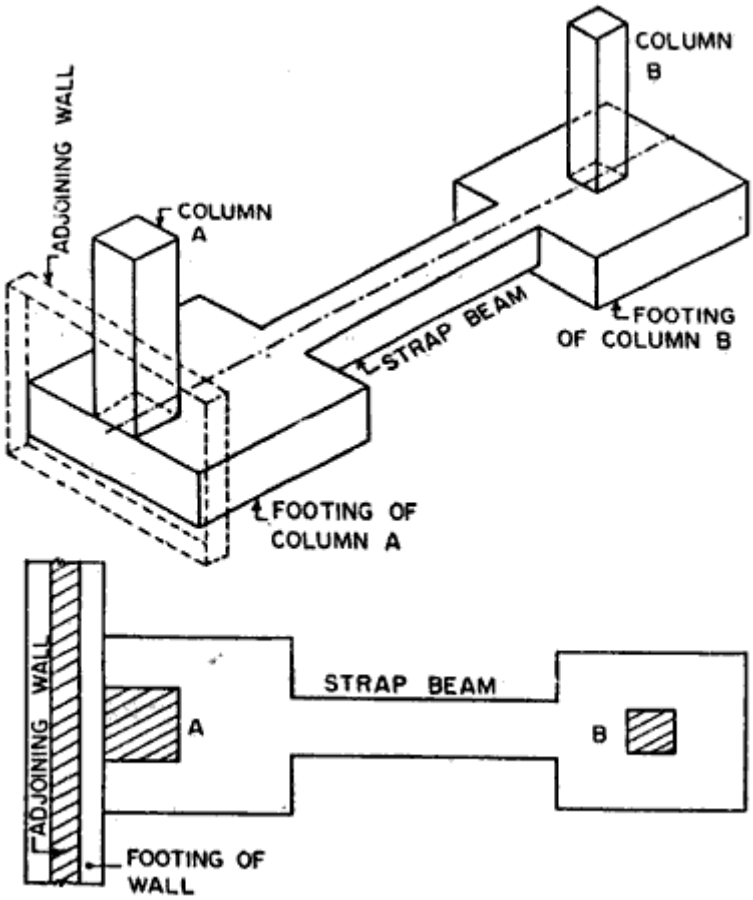
Combined footing is provided under the following circumstances:

1) When columns are very near to each other and their individual footing overlaps.
2) When bearing capacity of soil is less then it requires more area under individual footing.
3) When the end column is located st or near the property line and its footing cannot be extended on the side of property line.

The aim of providing combined footing is to get uniform pressure distribution under the footing. To achieve this objective the CG of the footing area should coincide with the CG of the combined loads of the column.

3) Strap footing: If the Independent footings of two columns are connected by a beam then it is called as strap footing. A strap footing may be used where the distance between columns is so great that the combined trapezoidal footing becomes quite narrow with high bending moments. In that case each column is provided with its individual footing and a beam is used to connect the two footing. The connecting beam is known as a strap.

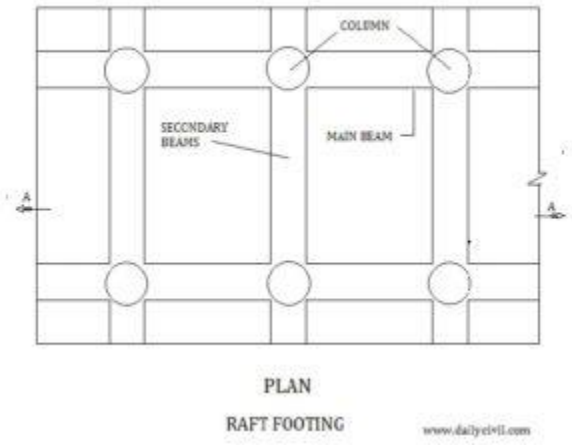
The strap beam does not remain in contact with soil and thus it does not transfer any pressure to soil.



4) Mat Foundation (Raft Foundation)

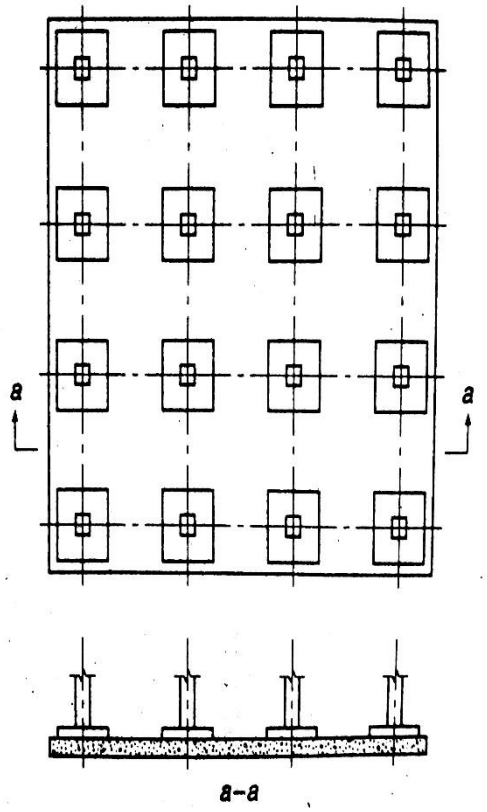
- It is a combined footing that covers the entire area beneath a structure and supports all the walls and columns.
- It is used when the allowable soil pressure is low and building loads are heavy.
- Overall settlement of the structure is reduced, as the total load of the structure is distributed over large area and thus intensity of pressure on the sub soil is reduced to minimum.
- When spread footing would cover more than 50% of the constructed area then it may prove economical to use raft foundation.
- They are also used where soil mass contains compressible lenses or the soil is sufficiently erratic so that the differential settlement would be difficult to control.
- The raft or mat tends to bridge over the erratic deposit and reduce the differential settlement.
- This foundation is found more suitable when heavy structures are to be built on soft made up ground or marshy land having uncertain behavior.
- Raft foundation is also used to reduce settlement above highly compressible soil.

Mat foundation.



PLAN

RAFT FOOTING



DEEP FOUNDATION:

- When a stratum of good bearing capacity is not available at reasonable depth i.e. D > B and where other types of foundations such as grillage or raft foundations are not suitable, then deep foundation must be adopted to attain a bearing stratum which will be suitable in all respect
- In deep Foundation the depth to width ratio is usually greater than 4 to 5.
- Deep foundations as compare to Shallow foundations distribute the load of the super structure vertically rather than laterally.
- Deep foundations are provided when the expected loads from superstructure cannot be supported on shallow foundations.
- In addition to the above, there may be many other conditions which may require deep foundation for scouring stability and durability of the structure.
- For example, in bridge construction, the pier must be founded well below the scouring depth, even though good bearing stratum may be available at shallow depth.

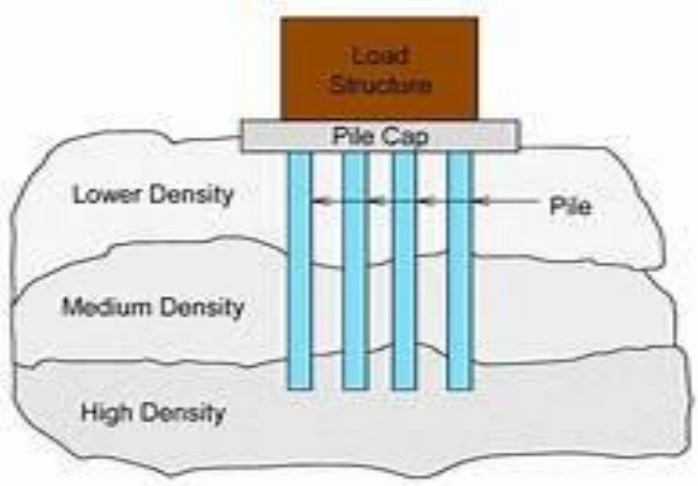
TYPES OF DEEP FOUNDATION:

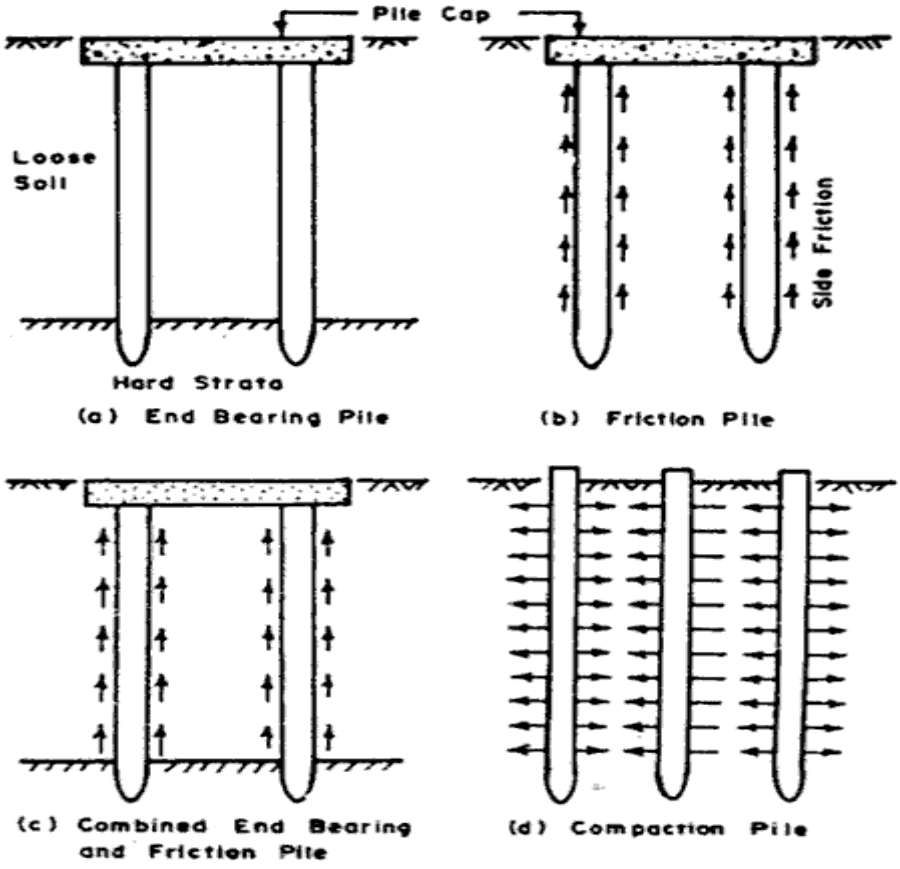
1) Pile Foundation
2) Pier Foundation
3) Well foundation or Caisson

1) **Pile Foundation:**

- Pile foundation is that type of deep foundation in which the loads are taken to low level by means of vertical member (Pile).
- A pile is defined as a shaft of suitable diameter employed to transfer the loads deep into a soil which may be capable of sustaining the load of the structure.
- Pile may be of timber, concrete or steel.
- A pile may be short or long.
- A pile is considered to be long when its length is more than 30 m.
- Pile foundation is generally adopted when the spread foundation, raft or grillage foundations are likely to be unsuitable, very expensive or practically impossible.
- In case of compressible soil, soil of made up type, water-logged soil, piles are usually used advantageously for foundation for any type of construction.
- Piles are usually used for foundations of buildings, bridges, piers, docks, etc.

Pile Cap:
Pile caps are thick slabs used
To tie a group of piles together
To support and transmit column
Loads to the piles





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PILE FOUNDATION IS USED WHEN:

• The soil near the surface doesn't have sufficient bearing capacity (Weak) to support the structural loads.

• The estimated settlement of the soil exceeds tolerable limits

• Differential settlement due to soil variability or non-uniform structural loads is excessive.

• Excavations to construct a shallow foundation on a firm soil are difficult or expensive.

Based upon the function piles are classified as:

(i) Bearing Piles

(ii) Friction Piles

(iii) Fender Piles

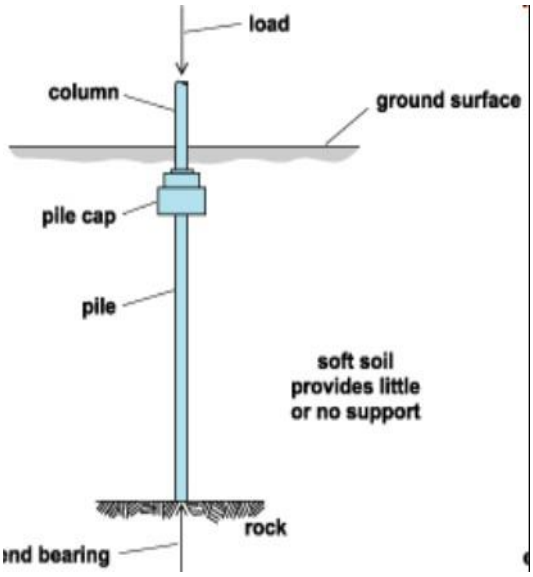
(iv) Anchor Pile

(v) Batter Piles

(iii) Sheet Piles

1) End Bearing Piles:

- This Piles are driven into the ground until a hard stratum is reached.
- This piles acts as pillars supporting the super-structure and transmitting the load to the ground.
- If the load is supported by resting the pile On very hard stratum then it is called end bearing piles
- Piles, by themselves do not support the load, rather acts as a medium to transmit the load from the Foundation to the resisting sub-stratum.

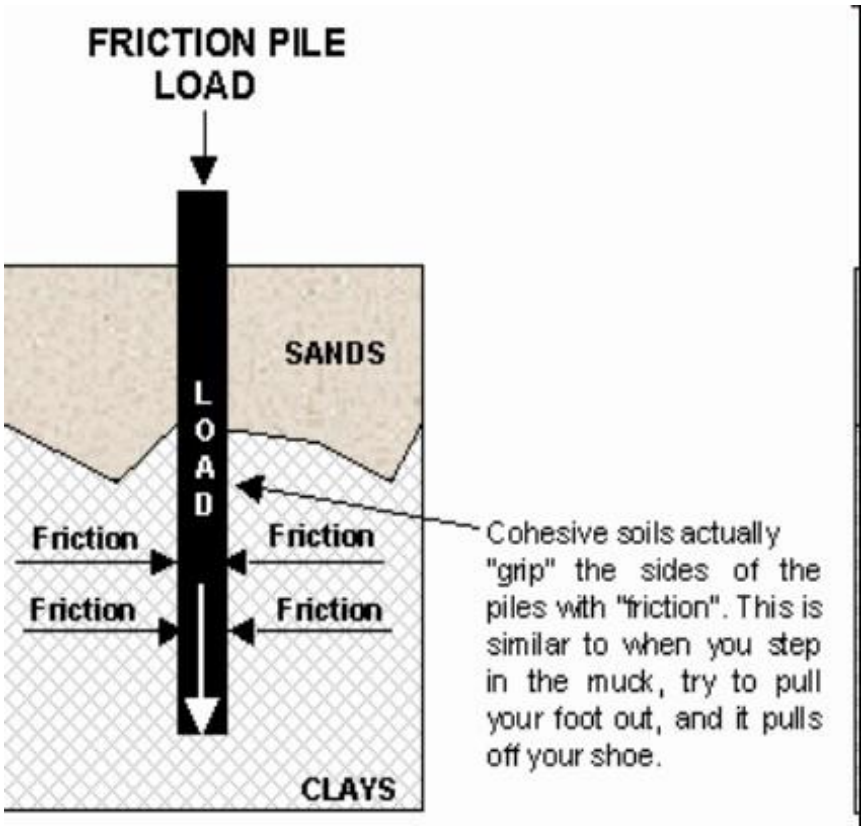


2) Friction pile:

- Piles are driven at a site where soil is weak or soft to a considerable depth and it is not economical or rather possible to rest the bottom end of the pile on the hard stratum,
- Load is carried by the friction developed between the sides of the pile and the surrounding ground (Skin friction).
- The piles are driven up to such a depth that skin friction developed at the sides of the piles equals the load coming on the piles.

The load carrying capacity of friction pile can be increased by-

- **increasing diameter of the pile**
- **driving the pile for larger depth**
- **grouping of piles**
- **making surface of the pile rough**



Anchor Piles: Piles are used to provide anchorage against horizontal pull from sheet piling wall or other pulling forces.

Compaction piles: When piles are driven in granular soil with the aim of increasing the bearing capacity of the soil, the piles are termed as compaction piles.

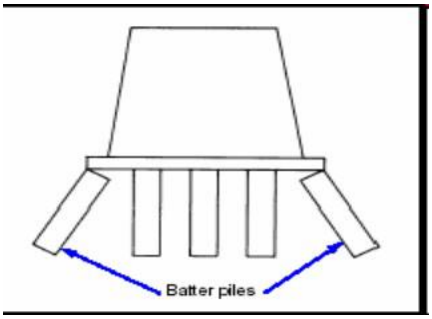
Batter piles: Piles are driven at an inclination to resist large horizontal and inclined forces**.**

Fender piles: Piles are used to protect concrete deck or other water front structures from the abrasion or impact caused from the ships or barges.

Sheet Piles

Sheet piles are used for the following purposes:

- To construct retaining walls in docks, and other marine works.
- To protect erosion of river banks.
- To retain the sides of foundation trenches



Under- Reamed Pile Foundation:

Under-reamed piles are bored cast in situ concrete piles, having one or more bulbs formed by enlarging the bore hole by an under-reaming tool. This piles widely Used in Situation where Foundation are required to be taken down at certain depth to avoid Undesirable effect of moisture change as in case of expansive soil (Black cotton soil).

If this bulb is taken or provided at a level lower than the critical depth of moisture movement in expansive soils then the foundation will get anchored to the ground and it would not move with the movement (i.e. swelling and shrinkage) of the soil.

- These piles may vary from 15cm dia to 50cm dia and are suitably spaced. Special under reaming tools are available with the help of which this piles are bored at site and then concreted, this piles are nominally reinforced to take tensile stresses.
- When the pile has one bulb it is known as single under reamed pile, while the pile with more than one bulb is known as multi under reamed pile.
- Generally the diameter of the under reamed bulb is kept equal to 2.5 times the diameter of the pile stem. However it may vary from 2 to 3 times the stem diameter, depending upon the design requirement and feasibility of construction.

Under reamed pile foundation is widely used under following circumstances:-

1) When the soil has poor bearing capacity and foundation has to be taken at lower level specifically in case of soft soils.
2) These piles provides anchorage against the lateral and uplift forces hence it is advantageous to use under reamed pile foundation in case of expansive soil.
3) This piles widely Used in Situation where Foundation are required to be taken down at certain depth to avoid Undesirable effect of moisture change as in case of expansive soil.
4) Providing foundation through filled up soil deposits or reclaimed soil.

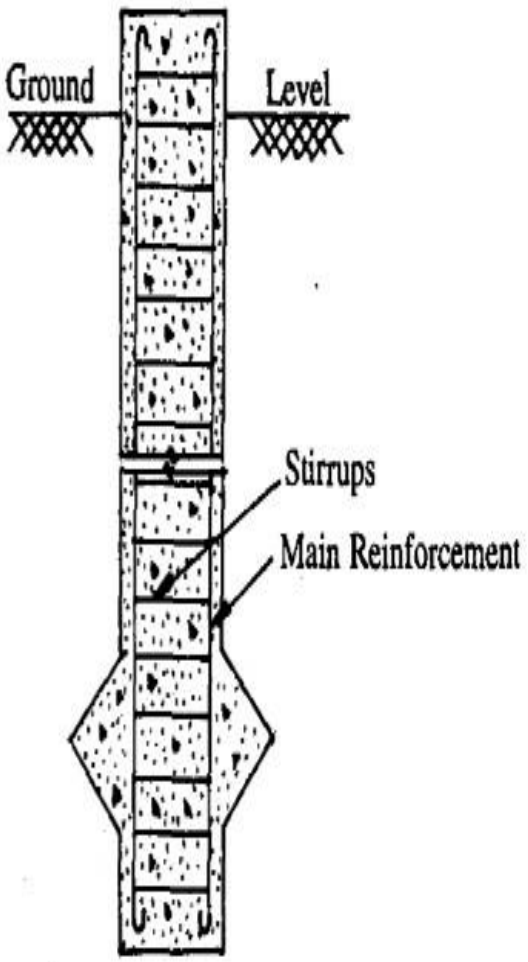
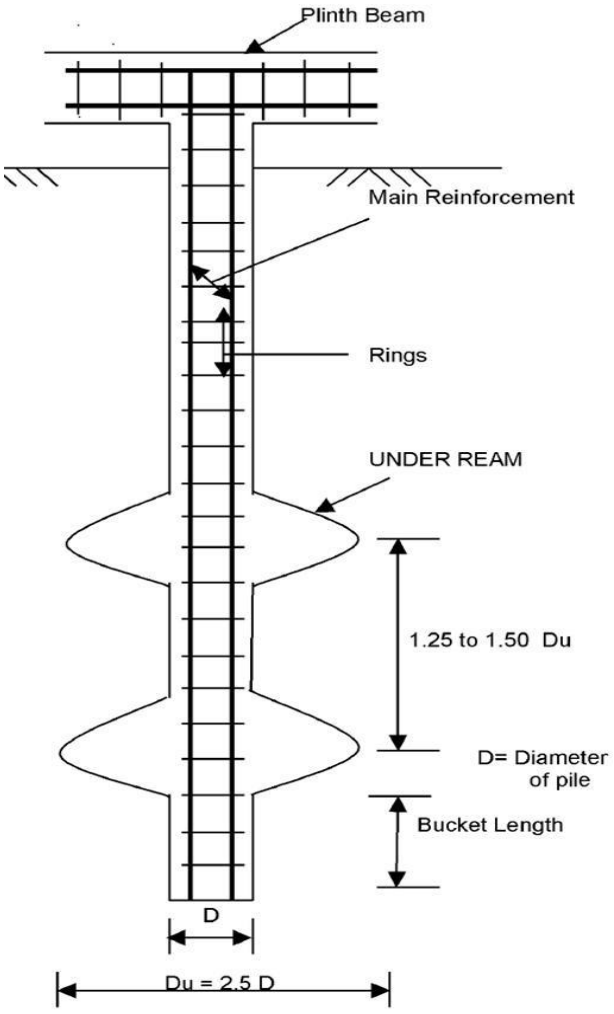


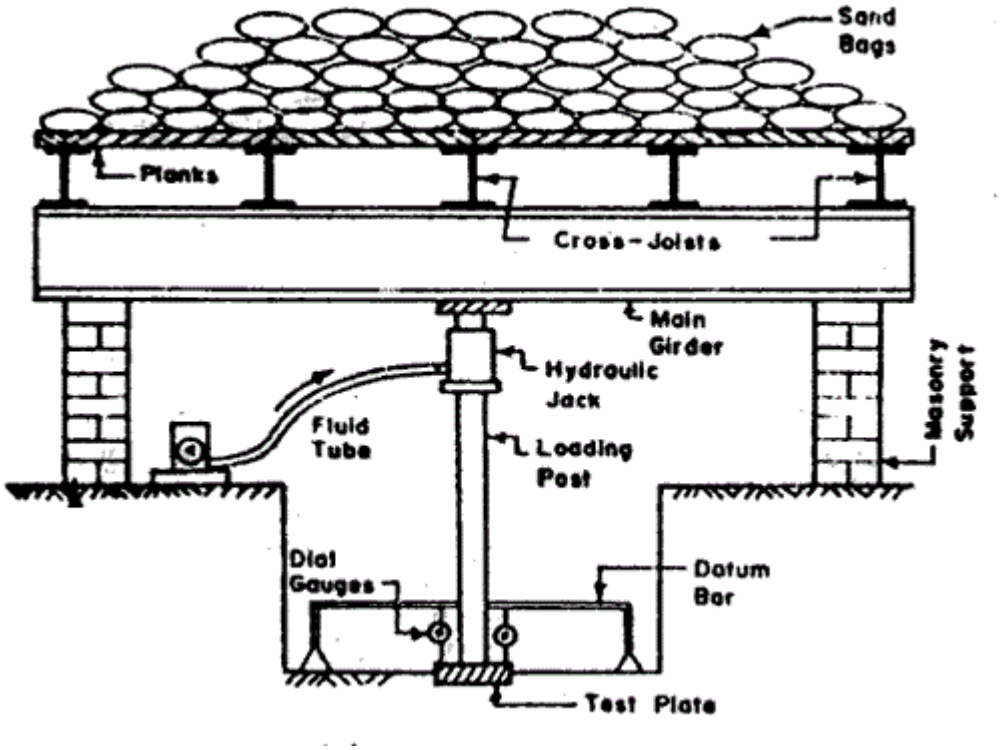
Fig. 2.4 *Under-reamed pile*



Under reamed pile with two under reams

PLATE LOAD TEST:

Plate load test is a field test use to determine the ultimate bearing capacity of soil and the probable settlement under a given loading. The test essentially consist of loading a rigid plate (usually steel plate) at a foundation level and determining the settlement under each load increment. The ultimate bearing capacity is taken at which the plate starts sinking at a rapid rate. The plate is square of minimum size $30cm^2$ and maximum size of $75cm^2$.



Procedure:

1) The test pit and the square hole for the steel plate are made. The plate is firmly seated in the hole. If the ground is slightly uneven a thin layer of sand is spread below the plate.
2) Indian standard (1888-1982) recommends a seating load $70g/cm^2$ or $(0.7t/m^2)$ which is released before the actual test is started.
3) The load is applied with the help of hydraulic jack preferably provided with remote control pumping unit.
4) The load is applied in convenient increment say about one fifth of expected safe bearing capacity or one tenth of expected ultimate bearing capacity.
5) The settlement of the plate is observed by two sensitive dial gauges which are fixed at diametrically opposite ends and supported on a suitable datum.
6) As the plates settles the ram of the dial gauges moves down and the settlement is recorded. The load is indicated on a load gauge of hydraulic jack.
7) Settlement should be observed for each increment of load after an interval of 1, 4,10,20,40 and 60 mints, therefore at hourly interval until the rate of settlement becomes less than 0.02mm per hour then the next load increment is applied.
8) The settlement load curve is plotted.

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